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Experiment of deuterium absorption and permeation due to plasma irradiation in the compact PWI simulator APSEDAS

PWI模擬実験装置APSEDASにおけるタングステン試料の重水素透過実験

Koichiro Honda[1], Aleksandr Rusinov[1], Mizuki Sakamoto[2], Akihide Fujisawa[3], Naoko Ashikawa[4], Tatsuo Shoji[5], Masayuki Tokitani[4], Mitsutaka Miyamoto[6], Naoaki Yoshida[3] and Tetsuo Tanabe[1]

本多耕一郎[1], Aleksandr Rusinov[1], 坂本瑞樹[2], 藤澤彰英[3], 芦川直子[4], 庄司多津男[5], 時谷政行[4], 宮本光貴[6], 吉田直亮[3], 田辺哲朗[1]

Interdisciplinary Graduate School of Engineering Sciences, Kyushu University, Kasuga, Fukuoka 816-8580, Japan[1]
Plasma Research Center, University of Tsukuba, 1-1-1 Tennodai, Tsukuba, Ibaraki 305-8577, Japan3-1-1-4F[2]
Research Institute for Applied Mechanics, Kyushu University, Kasuga, Fukuoka 816-8580, Japan[3]
National Institute for Fusion Science, Toki, Gifu, 509-5292, Japan[4]
Department of Engineering, Nagoya University, Nagoya, Aichi, 464-8601, Japan[5]
Department of Material Science, Shimane University, Matsue, Shimane 690-8504, Japan[6]
九州大学総合理工学府　〒816-8580　福岡県春日市春日公園6-1[1]
筑波大学プラズマ研究センター　〒305-8577　茨城県つくば市天王台1-1-1[2]
九州大学応用力学研究所　〒816-8580　福岡県春日市春日公園6-1[3]
核融合科学研究所　〒509-5292 岐阜県土岐市下石町322-6[4]
名古屋大学工学部　〒464-8601　愛知県名古屋市不老町[5]
島根大学総合理工学部　〒690-8504　島根県松江市西川津町1060[6]

Plasma driven permeation (PDP) of deuterium through a tungsten sample under the condition of low energy and high flux plasma exposure was carried out in the compact PWI simulator APSEDAS. As the sample temperature increased, the permeation flux increased as well. At 630K and 670K, the permeation flux is constant in steady state, whereas, at 700K, 740K, and 780K, we can observe decreasing of the permeation flux in a steady state regime.

1. Introduction

Hydrogen isotope implanted into a plasma facing component is either reemitted into the plasma, or retained in or permeated through a plasma facing component to the backside. In the view point of safety of the fusion reactor, it is important to understand hydrogen isotope permeation behavior through a plasma facing component. Various experiments of plasma driven permeation (PDP) and ion driven permeation (IDP) have been performed [for example: 1-4].

In this study, PDP flux through a tungsten thin disk, which was exposed to the low energy and high flux deuterium plasma, was investigated in the compact PWI simulator APSEDAS. The flux of gas permeated through the tungsten sample was measured by a quadrupole mass spectrometer (QMS).

2. Experimental

A schematic diagram of the experimental apparatus is shown in Fig. 1. A plasma column is

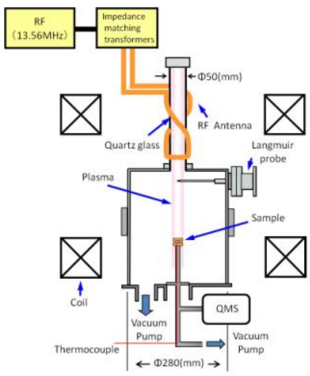

Fig. 1. Schematic diagram of the PWI simulator APSEDAS

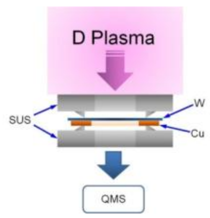

Fig. 2. Schematic diagram of the sample holder

sustained by 13.56 MHz RF field and its diameter is about 50mm. The sample was pinched by stainless steel flange and Cu normal gasket as shown in Fig. 2. The irradiated area was ϕ16mm. The sample temperature was measured by a thermocouple contacted with the backside of the sample. The plasma parameters were measured by a Langmuir probe. The permeation flux was measured by QMS, which was installed at the upper of the pump. Several masses including HD and D_2 were monitored. QMS signals were calibrated by using a standard helium leak bottle. HD calibration factor was assumed to be the same as that of D_2. The pressure of deuterium gas in the upstream chamber during exposure was maintained at about 2.0×10^{-2} Torr and the base pressure of the downstream (permeation) side was kept at about 1.5×10^{-7} Torr.

The tungsten disk sample (ϕ20mm$\times$1mm) used in this study was produced by A.L.M.T. Corp. The sample was polished both sides mechanically and ultrasonically cleaned in acetone and ethanol, and annealed in vacuum at 1173K for 1 hour before experiments.

3. Results and discussion

The tungsten sample was exposed to the low energy plasma (6~9.7eV) of which flux was about $2.1\sim4.0\times10^{21}$ D/m^{2}s.

The time evolutions of permeation fluxes of HD, D_2 and the sample temperature are shown in Fig. 3(a), where the sample temperature was changed by RF power step by step. The time evolutions of permeation fluxes of HD, D_2 and the sample temperature until 2 hours from the start of the plasma exposure are also shown in Fig. 3(b). The permeation flux was observed just after the start of the plasma exposure. The permeation flux decreased as soon as the plasma exposure was stopped. It took long time to reach steady state at first. As the sample temperature increased, the permeation flux increased as well. The increase in the permeation flux is attributed to the increase in the diffusion coefficient due to the sample temperature increase. At 630K and 670K, the permeation flux is constant in the steady state, whereas, at 700K, 740K, and 780K, we can observe decreasing of the permeation flux in the steady state regime. When the sample temperature decreased to ~630K again, the permeation flux was reduced to a little higher level as the first steady state at 630K.

4. Summary

To investigate behavior of deuterium permeation, Plasma driven permeation of deuterium through the tungsten sample was carried out in the compact PWI simulator APSEDAS. The permeation flux began to increase as soon as the plasma exposure started, and began to decrease when the exposure was stopped. As the sample temperature increased, the permeation flux also increased because of a diffusion coefficient rising. However, the permeation flux gradually decreased in the steady state regime at high temperature.

To investigate the behavior of permeation in more detail, we will simulate using the simulation code TMAP 7 and compare to experimental results.

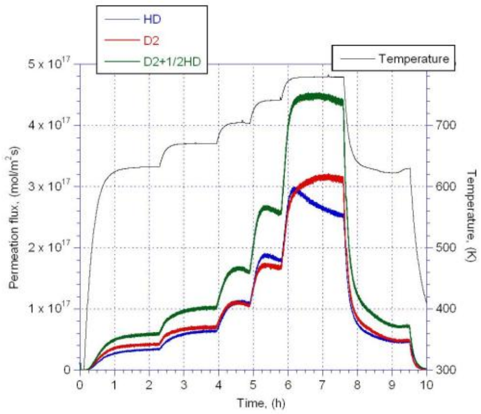

Fig. 3(a). The time evolutions of permeation fluxes of HD, D_2 and the sample temperature

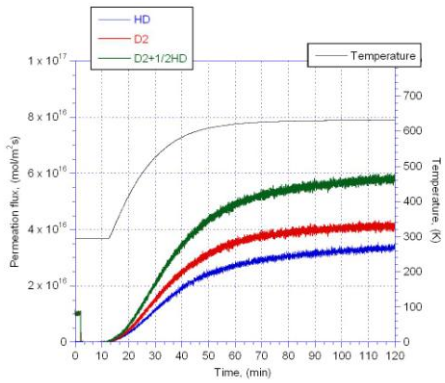

Fig. 3(b). The time evolutions of permeation fluxes of HD, D_2 and the sample temperature (~2h)

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